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ENZYMATIC STAINING OF HARDWOODS PREVENTION AND CONTROL

Raymond Hotte
Buckman Laboratories, 351 Joseph Carrier., Vaudreuil, PQ J7V 5V5

1. Review of Problems for the Lumber Industry

Sawmills have been experiencing stain problems in lumber for decades.

Defects caused by insects, fungi, and chemical stains can affect the appearance and strength of wood. Damage caused by insects will not be discussed in this paper.

Staining usually results in a monetary loss to the lumber producer, because the material (lumber) is drastically downgraded.

Total amount of lost dollars for the Canadian hardwood industry is very difficult to evaluate. Percentage of lumber downgraded because of sapstain or chemical stain can vary in average from nil to 5% of production, but can be as high as 10, 15 or even 25% or more, in some small operations. In 1990, a survey of the Canadian hard maple producers evaluated that over 6 million dollars were lost because of sticker stain downgrading alone. Millions and millions of dollars are lost each year because of stain related problems to the lumber industry.

In the past years, customers requirements have demanded that manufacturers provide lumber which is attractive, and of a specified, uniform and replicable color.

In this paper, I will review and discuss the problems associated with the prevention and control of stains on lumber.

I will review Microbiological Stains, also called Sapstain or Blue Stain and the more complicated Chemical/Enzymatic Stains.

Photo 1.

2. Microbiological Stains Vs Chemical / Enzymatic Stains

Detrimental color changes in lumber can be biological, such as blue stain from fungal growth, or chemical, such as enzymatic or oxidative staining, which would include darkening in maple, pinking in hickory, sticker stain and brown stain in pines and hemlock.

There are two main groups of stains that occur in wood;

Microbiological Stains (Sapstain, Blue Stain) :

The first group of wood stains is called ``Fungal Stains`` and includes sapstain (blue stain). The color is caused by fungi growing through the sapwood of logs and lumber. Fungal stains or biological stains are the result of living organisms interacting with the wood or wood components.

There are four essential growth elements for sapstain fungi to exist. They are:

- Temperature
- Oxygen
- Moisture
- Food supply

Temperature: optimum temperature range for sapstain to grow is 70-90F. Below 50F, the fungus is essentially dormant. The fungus is killed from exposure to temperature of 130F or more.

Table 3. Effect of Temperature on Fungal Growth

Temperature	Fungal Growth
Less than 32°F	None
32 to 65°F	Low to medium
66 to 90°F	High
91 to 110°F	Low to medium
Greater than 110°F	Killed

Oxygen: oxygen is essential for the development of any fungi. In living trees, or in logs that are continually sprayed with water, there is not sufficient oxygen present for the fungus to grow. However, once drying starts, the required oxygen becomes available. So stain formation starts as soon as the tree is cut.

Moisture: sufficient moisture must be available for the fungus to grow. The greatest risk of staining damage exists at moisture contents above 40%.

Table 2. Effect of Moisture Content on Fungal Growth

	Types of Fungal Growth		
Moisture Content	Rot	Stain	Mold
Green	High	High	High
Partly air dried	Medium	Low	Low
Air dried to less than 30%	None	Low	Low
Air dried to less than 22%	None	None	Low
Air dried to less than 20%	None	None	None
Kiln dried to less than 20%	None	None	None

Food Supply: the sap stain fungus food supply is the sugar in the sapwood. Usually, the supply of sugar in the hartwood is inadequate for the fungi to exist. Sapstains are located in sapwood and under bark.

Types of fungi. Fungi that affect lumber can be divided into two groups;

- Discoloring Fungi: includes stains and molds, and generally affect only the appearance of the wood.
  Sapstain fungi can cause both surface discoloration and interior discoloration on hardwoods.

Photo 2 and 2a. Sapstains

- Decay or Rot Fungi: weaken the wood as well as alter its color.Divided into brown and white rots. Brown rots darken the wood. Both types of rots soften the wood, finally destroying its structure.

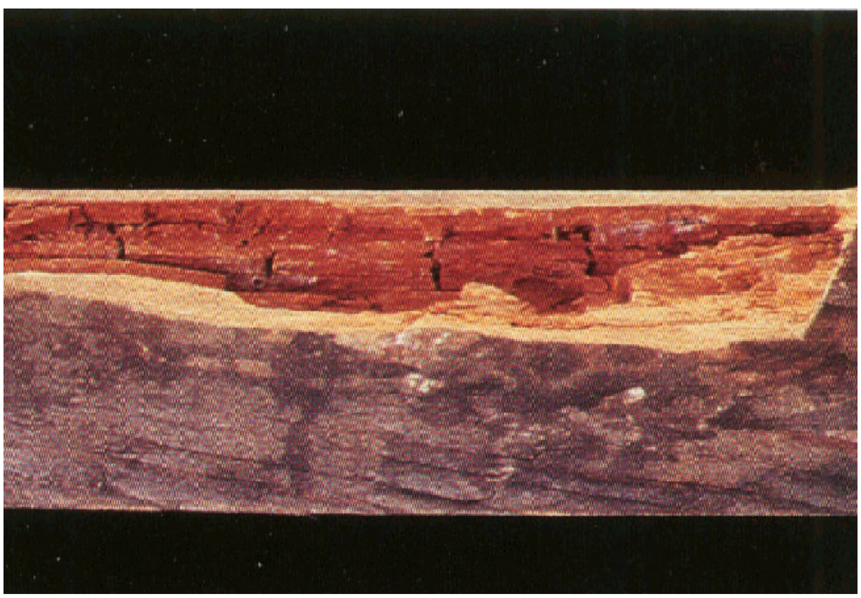


Photo 3. Rot fungi

Chemical / Enzymatic Stains:

Chemical/Enzymatic stains are the second main group of stains that can occur in wood. They occur during storage and drying and are a result of a chemical change within the wood.

They form when freshly cut or sawn hardwood containing living wood (parenchyma) cells comes into contact with air resulting in the formation of amber globules with a positive starch reaction in the wood cells.

Chemical/Enzymatic stains can be divided into two types: interior oxidation stains and exterior chemical stains. These stains should not be confused with fungal discoloration. Fungal and chemical stains can and often do occur together.

Interior Oxidation Stains: can be divided into;

- Brown stains
- Interior gray stains
- Sticker stains

They vary in color from grayish in red oak (gray stain) to brownish in maple (brown stain) and in white pine (coffee stain).

On lumber, they can be very shallow and eliminated by normal planing, extended through the piece or found only in the interior. Chemical stain may also only be restricted to a small area such as the area under a sticker (sticker stain).

Discoloration associated with oxidation stains usually occurs during drying. It results from the oxidation of certain colorless chemicals that occur naturally in wood. Upon oxidation, these chemicals become darker in color. Enzymes are probably involved in this oxidation process.

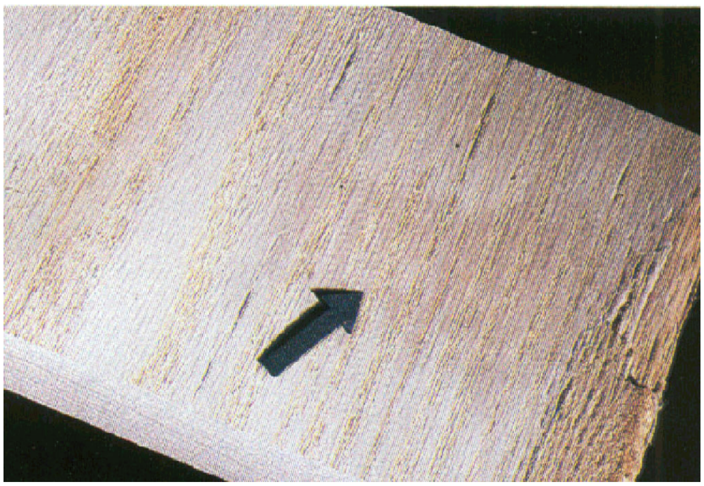
Enzymatic stain may penetrate deeply into the sapwood of hardwood species and usually are not easily removed by surface planing.

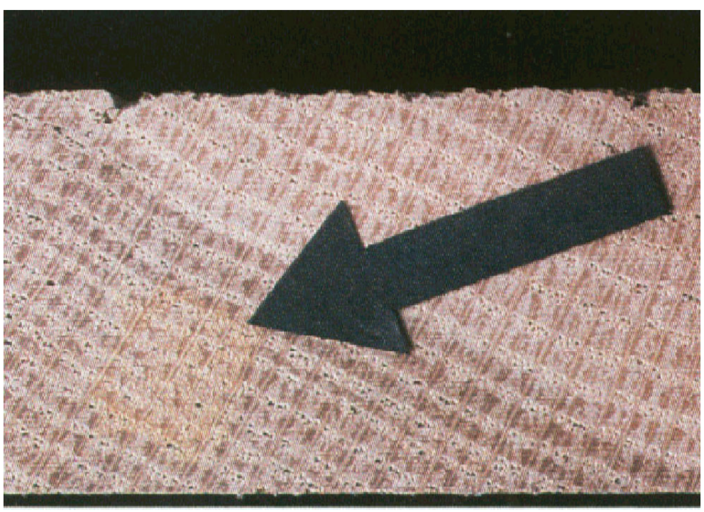
Moisture content, temperature, and oxygen must be at favourable levels for the oxidation to occur. The chemical reactions can start in freshly cut lumber when it starts to dry.

High humidity (80 % or greater) coupled with warm temperature (70F or higher) promote interior discoloration. Very little staining, if any, occurs below 50F.

Exterior Chemical Stains: can be divided into;

- Iron stains
- Water stains





Photos 4, 5, and 6. Chemical / Enzymatic stains

These stains occur when wood comes in contact with materials from an outside source.

Iron tannate stain is the blue-black stain that forms on the surface of hardwoods and generally can be removed by surfacing or planing. Iron tannate stain forms when the tannic acid present in hardwoods (high-acid wood like Oak) reacts with iron from steel equipment (carrying chains, straps, etc.) or water during processing (process water, steel dip tanks). Blackened water from an iron dip tank can give a slight, even discoloration of lumber.

Water marks occur when water droplets are deposited on lumber during the drying process. These discolorations can usually be surfaced out during normal planing.

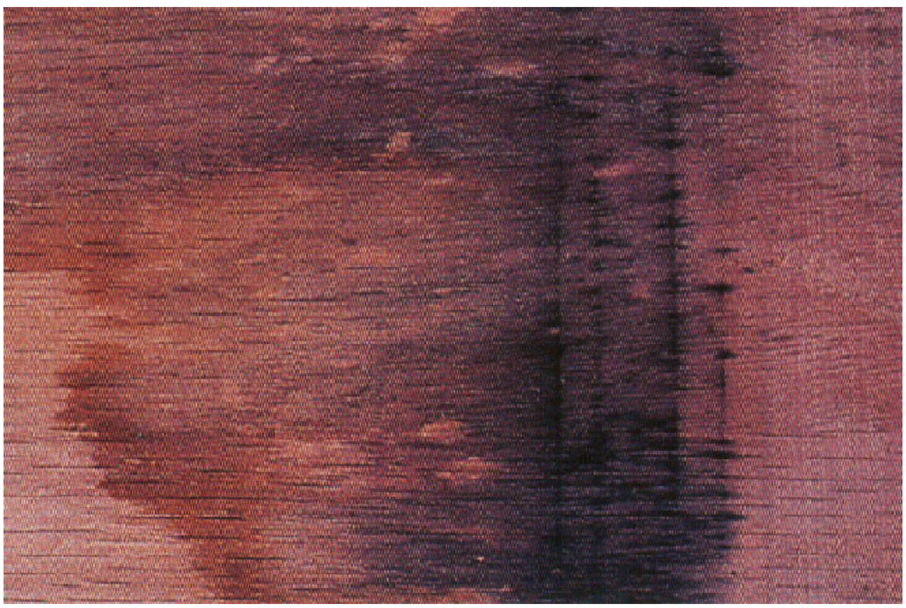


Photo 7. Iron Stain and Water Marks

3. The Role of Moisture Content

The main cause of most stains is slow drying at the start of the drying cycle when the wood is at its wettest. In wood, the greatest risk of staining occurs when the moisture content is above 40%.

Regardless of the type of drying method used, there is a maximum or safe rate of moisture loss per day for each species and thickness, to prevent staining.

Moisture content clearly plays an important role in determining the susceptibility of wood to attack and continued activity by insects, fungi, or chemical stains.

Table 4. Industry Terms for Moisture Content

Industry Term	Moisture Content
Green	Greater than 30%.
PAD (partly air dried)	Surface less than 30% but interior greater than 30%.
AD (well air dried)	Surface and interior less than 30%.
KD (kiln dried)	Surface and interior at or around 6 to 8%.

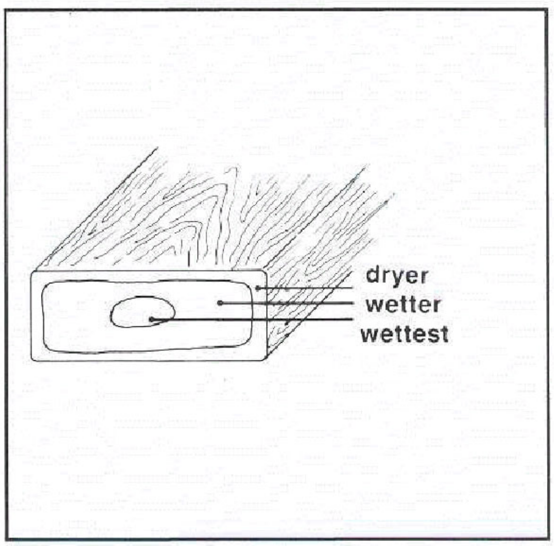


Figure 1. Moisture levels within a board during drying.

These terms generally describe an average moisture condition within the board. The moisture content can vary considerably throughout the board, particularly during the early stage of drying. Moisture gradient.

It is important to remember that while the surface may be dry enough to insect or fungi attacks or to avoid discoloration from chemical stains, the interior may still be wet enough for the defect-causing agents to continue their activity.

Rewetting of a board surface during drying can create conditions favourable to attack by certain agents. Moisture can be picked up immediately from rain or melted snow.

High humidity in the yard, predrier, or even in the kiln can also result in an attack or activity by certain agents.

4. Stain Control, Prevention and Protection

- Identification Type of Stains
- Prevention and Protection
- New Chemistry : Busperse 293, Busperse 2290

Identification Type of Stains

It is sometimes difficult to distinguish fungal from chemical stains.

- A bleach solution will remove the surface discoloration caused by mold and fungi but does not affect chemical stains.
- A concentrated solution of oxalic acid will partially or completely bleach chemical stains but will not affect fungal stains appreciably.

Photo 8. Iron stain bleached with Oxalic acid

Stain Prevention and Protection.

- Logs
- Green lumber
- Dry lumber

Logs: - **Water** spraying
- Logs End-sealing
- Spraying with Fungicide

- Debark logs or convert to lumber quickly, particularly in warm weather.
- Best protection by continuously spraying the logs with water (oxygen control).
- Water spraying prevents insect and stain attacks.
- Chemical stains can occur, if logs are left more than four to six weeks under spray.
- Spraying with fungicide is difficult and not very effective on large scale.

Green Lumber: - Rapid drying of lumber below 30% moisture.
- Dipping or spraying with chemicals (fungicides).
- Good Air Drying.

- Fungal and insect damage can be prevented in green lumber by rapid drying, by dipping or spraying the lumber with a suitable fungicide.
- In warm weather, rapid stacking of lumber for air-drying or kiln drying minimizes the risk of fungus attack or certain chemical stains.
- Chemical treatment for sapstain should be used if the lumber will remain moist for several days at a daytime temperature greater than 70F or if the appearance of the wood is important.
- Surface application of fungicides to infected and discolored lumber will kill the fungi but not remove discoloration.

Microbiological chemical treatment of green lumber: steps for success

1. Lumber must be treated immediately after sawing
2. All lumber surfaces must be covered
3. Chemical should be used at label recommended level

The chemical used to prevent fungus attack will not prevent chemical (oxidative) staining. Dipping for sapstains or rewetting the lumber can accelerate or increase the chances of chemical stain formation.

Photos 9 and 10. Dip tank systems

Prevention for chemical stains (keys):

1. There is no sure method for completely preventing this decoloration.
2. Avoid long storage of logs or dead-pile stacked lumber (log age).
3. Stacking the lumber on dry stick soon after it is cut from the log.
4. Dry lumber as quickly as possible.
5. For prevention, purchase logs only during the winter months (harvest season).
6. Adequate and effective dryers schedules and temperatures.
7. Effective and good air flow and air drying in outside yards or dryers.
8. Add a metal ion sequestrant agent to lumber sapstain dip treatment.

Fewer variations in color are observed in lumber sawn from logs cut (harvested) in winter.

Drying schedules are more important factors in determining wood color than log storage or harvest season.

Dry Lumber: - Keep moisture level low.

- Fungi and chemical stains can attack dry lumber that has been rewetted.
- It is important to keep wood dry during storage. Complete protection from rain is essential.

<u>New Chemistry: use of metal ions sequestrant</u>

<u>Busperse 293 and Busperse 2290</u>

Busperse 293 and 2290 are two sequestering agents used in the control of metal ions in wood soaking solutions. These products generate a significant reduction or the elimination of problems related to chemical and enzymatic stains on your wood.

Products are used directly into the dip solution (dip tank or spray applications) and are compatible with most fungicide (Busan 1030).

Busperse 293: Iron Stain Preservative

- Aqueous solution of an effective metal ion sequestrant.
- Maintains the natural color and bright appearance of wood.
- Protects lumber from iron tannate stains from equipment.
- Used for over 12 years to prevent iron stain formation and discoloration of hardwood dip solutions, when used in steel dip tank with Busan 1030 (widely used sapstain fungicide).

Photo 11. Dip tank solution with and without Busperse-293

Photo 12. Busperse-293 evaluation on lumber. Red Oak board with Iron Stain

Busperse 2290: Chemical / Enzymatic stain control

- Aqueous solution of an effective metal ion sequestrant and an enzymatic stain cleaner.
- Maintains natural color and bright appearance of hardwoods.

- Protects lumber from iron tannate stains.
- Cleans iron tannate stains from surface of hardwoods.
- Protects surface of lumber from enzymatic stains.
- Cleans enzymatic stains from the surface of hardwoods.
- Product being evaluated in white pine bulk dip tank for brown stain control (coffee stain).

Work on the application of these products continues Treatment and control of chemical / enzymatic stains on lumber is much more difficult then sapstain control.

Objective is for the producer to reduce the risk of staining. Good and safe handling of logs and lumber will always be needed to prevent staining and keep lumber value.

5. Future of Stain Control (R & D)

Many chemicals and treatments have been used and evaluated in the past to reduce the action of enzymes causing lumber discoloration (staining), with very limited success. The high number of factors affecting chemical staining has resulted in mixed results and treatments that are very difficult to reproduce.

- Borates
- Sodium Fluoride (coffee stain on white pine)
- Enzyme inhibitors
- Sodium Bisulfate (interior graying on hardwood)
- Log fumigation

Lots of work and research have been done on trying to understand and control chemical enzymatic staining of lumber.

More research will be done to understand the chemistry behind all this and to develop new ways to control it.

Conclusion

Chemical stain formation during drying in hardwoods is a complex process and further work is required to understand its chemistry, which may lead to the development of new chemicals and new methods of protection against its occurrence.

Problems associated with chemical non-biological stains on lumber have been reduced a lot over the last 10 years. Mainly because of the worldwide lumber market situation and the needs for the producers to improve their complete operations and to control cost.

Stickers design improvement has reduced problems associated with sticker stains formation on hardwoods.

Logs harvest, log age and processing schedules have been improved and have reduced problems associated with oxidation stains, like coffee stain on white pine.

Dryers improvement and better drying schedules knowledge have drastically reduced the formation of chemical / enzymatic stains in hardwoods.

More work will be done in laboratories to find new and better chemicals and more work will be done in the field with the producers to evaluate these new approaches and to help them reduce problems with stains on their lumber.

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